A Review of Plant-Based Diets in The Adult and Neonate in Terms of Cognitive, Neurological, and Psychiatric Function

Sadie Heiger

Abstract

In recent years, vegetarianism has become more common worldwide. Because of this, more studies have been conducted analyzing the effects of restrictive diets. As we look closer into the effects of diet on the body, connections have been made regarding the differences between an omnivorous and vegetarian diet, specifically regarding brain development. The differences in micronutrients (vitamins and minerals) and macronutrients (lipids, proteins, and carbohydrates) in vegetarian and vegan diets have been shown in some studies to impact neurological function. Plant-based and omnivorous diets have many different levels of nutrients that impact the brain's cognitive, neurological, and psychiatric functions. Through recent advancements in neuroimaging technology, we can assess the brain's growth and development in terms of structure and function. These technologies have improved how we can analyze how different dietary compositions affect the function and structure of the human brain. Our study will highlight the changes and patterns in brain development because of a plant-based diet and how it affects cognition and behavior.

Introduction

Energy is required to fuel development and growth in the body (Hall et al.). This energy comes from the food that we eat every day. In terms of neurological development, this energy is crucial to ensuring the healthy brain function of any given individual (Clemente-Suárez et al.). Different dietary compositions have shown varying intakes of critical vitamins and nutrients regarding neurological development. Specifically, when analyzing restrictive diets we can see wide-ranging variability in terms of measurable brain development at the neurological, psychiatric, and cognitive deficits (Berkins et al.; Byrne et al.; Zhang et al.). The analysis of this paper will focus on how vegetarianism and vegan diets affect neurologic, cognitive, and psychiatric development as well as how a plant-based diet can impact the function of an individual's brain. These results will be compared to individuals following an omnivorous diet. Vegetarianism is a diet in which an individual does not eat meat. Veganism, however, is a diet that excludes meat and all animal products (Petti et al.). Pescetarianism, which is a diet that includes fish and all animal products but no poultry or red meat, will be discussed as well. Vegetarianism and veganism are commonly referred to as plant-based diets and this term will be used to reference them together. This paper will examine the differences between plant-based and omnivorous diets and the effects that both have on the developing brain.

Vegetarianism has a rich history, stemming back to Greece in the sixth century (Harden). In more recent years, vegetarianism has become more common worldwide for a multitude of reasons, including more year-round accessibility, growing health concerns, and increased animal welfare activism (Mb). This has resulted in a significant increase in research on the effects of plant-based diets on health. According to a wide range of nutritionists and food experts, plant-based diets have been known to be linked to lower rates of cardiac disease, stroke prevention, obesity, and cancer (Tuso et al.). This can be attributed to lower levels of sodium, cholesterol, and saturated fats in plant-based diets (Tuso et al.). The disadvantages of this diet can include an increased likelihood of developing vitamin deficiencies that can lead to conditions such as anemia (Chouraqui). Anemia is the condition of having low iron levels in the blood, which can be caused by improper protein intake (Pawlak et al.). In regards to human brain development, these small vitamins and minerals can have a tremendous effect on our behavior, attitude, and overall psychological development (Berkins et al.).

Many critical vitamins and minerals aid in the development of neurological, psychiatric, and cognitive functions (Kennedy and Haskell). One example is Vitamin A, which is responsible for immune system support and growth and development (De Azevedo Paiva et al.). Vitamin B6, is responsible for energy levels and brain function (Tardy et al.). Vitamin B12 is responsible for helping with DNA growth and development, while Vitamin B9, also known as folate, is responsible for healthy cellular development (Tardy et al.). Finally, omega 3-6 is responsible for healthy brain development and energy function (Innis). Additional factors associated with prolonged vitamin deficiencies include muscle weakness and impaired eyesight (Jen and Yan). Long-term deficits in nutrient intake specifically in vitamin D and calcium have been shown to lead to osteoporosis (Heaney). Vitamin D deficiency has also been linked to a 300% increased risk of cardiovascular disease (Wang et al.). Deficiency in folate and folic acid are associated with severe neural tube defects as well as congenital heart defects. Supplementation or dietary intervention has been shown to reduce the rates of these vitamin deficiency-related diseases (Czeizel et al.).

Medical technology has rapidly evolved, including new tools such as MRIs and CTs for analyzing neurological activity. These technologies facilitate analysis of neurological development and change than ever seen before. The analysis of brain development and change is crucial because of how critically it affects the future of every individual (Stiles and Jernigan). Research has indicated that a plant-based diet can impact the brain’s development due to deficiencies in vitamins and nutrients including Vitamin B6, B12, folate, and omega-3 fatty acids. (Kapoor et al.; Firth et al.; Cheatham). Analysis of cognition, behavior, memory, and physical development of subcortical brain volumes can provide insight into the effects of vitamin deficiency. Due to the small sample size of studies in this field, clear conclusions cannot be drawn from the results of many of these studies. It has also been shown that in many cases the effect size for relationships between a plant-based diet and neurological development is small (Medawar et al.).

When analyzing the molecular composition of omnivorous and plant-based diets, a variety of differences have been observed most commonly surrounding protein intake and micronutrient composition (MacArthur et al.; Gibbs and Cappuccio). These differences were analyzed in a study reviewing plant-based diets from around the world, composed of observational and intervention studies that excluded diets that had been prescribed or an “overly restrictive” diet such as a raw food diet from 2000 to January 2020 (Neufingerl and Eilander). Out of the 141 studies analyzed, it showcased that, across the board, vegetarians and vegans had lower amounts of protein, but the majority did fall within the normal range. Additionally, fiber intake was also measured, and the highest fiber intake was found in vegans. Whereas in the meat eater population, the majority was under the recommended consumption. Vitamin consumption was analyzed in some of these studies and showed that individuals who ate plant-based diets were generally low in vitamin B12. This was concluded from observing 48 studies.

A protein is composed of an assortment of amino acids that are then formed into polypeptide chains and then folded to create the protein structure (Sun et al.). There are 20 essential amino acids, and our body can produce about 11 of them naturally. Dietary supplementation is the way we get the other nine essential amino acids (“Amino Acid”). Lack of protein has been shown to affect neurological health and decrease in neurotransmission and memorization (Sato et al.). This deficiency also causes muscle weakness and loss of muscle mass, known as sarcopenia (Beasley et al.). These effects can be attributed to how important amino acids are in cellular function in all areas of the body, including the brain. How a vegetarian compared to an omnivore consumes protein has shown to be very different. For omnivores, poultry and red meat are two of the most common sources of protein (Services) A study on protein intake showed that vegetarian and vegan-based diets were the lowest in protein intake. Additionally, the protein that plant-based individuals were ingesting was suggested to be more beneficial than the meat-based protein (Papier et al.). These proteins were considered more beneficial because they showed an overall lower risk of contributing to ailments such as obesity, heart disease, and stroke over time.

Research suggests that following a plant-based diet may have positive health-related impacts such as lower blood pressure and cholesterol along with a decrease in diabetes and significantly lower rates of heart disease (Kahleova et al.). However, it has been noted that following a plant-based diet may result in a higher likelihood of an individual developing nutritional deficiencies over time, leading to deleterious neurological impacts (Tuso et al.; Berkins et al.). Additionally, many scientists have attributed both positive and negative developmental factors related to plant-based diets and the brain development of adults, children, and unborn babies (Chaudron et al.; Cofnas).

Neonatal Development

Research has shown that the development of an individual's brain can be hindered by vitamin and mineral deficiencies caused by a vegetarian and vegan diet (Sanders). However, there is very little research to support the theory that vegan and vegetarian diets negatively impact a developing child's brain (Crozier et al.). When looking at the vegetarian diet as it affects pregnancy, research has not demonstrated that vegetarianism affects cognitive development or that it is linked to an unequal sex ratio of newborns (Cofnas). It was shown that vegetarian mothers give birth to much higher numbers of girls instead of boys due to the "selective spontaneous abortion" of male fetuses. Spontaneous abortion can be defined as the loss of pregnancy without additional intervention before the 20th week of pregnancy (Griebel et al.). This additional stress could be linked to a deficiency in vitamin B6 or B12 or a deficiency in omega-3-6 because they play an important role in behavioral function as well as neurological development (Cofnas). Lastly, it is now known that vegetarian mothers have lower amounts of specific omega-3- 6 fatty acids, also known as arachidonic acid and docosahexaenoic acid, compared to their omnivorous counterparts during gestation (Cheatham). This difference may lead to more noticeable behavioral issues in young children.

Cognitive Development of the Neonate

It has been noted that in infants, docosahexaenoic acid is a critical nutrient in terms of cognitive brain function (Brenna and Carlson). Arachidonic acid and docosahexaenoic acid (DHA) are nutrients responsible for aiding in the neurodevelopment process. Docosahexaenoic and arachidonic acids are omega-3 fatty acids commonly found in fish oils. They specifically assist in the functional and structural development of the brain (Niemoller and Bazan). Scarcity of this nutrient during the gestational period and in the child's infancy has been shown to result in cognitive and neurologic structural impairment. (Derbyshire). There is evidence of decreased cognitive development in infants and toddlers due to the absence of these nutrients (Brenna and Carlson).

The most notable time that a fetus is gaining this nutrient is the 2nd half of the gestational period and through the first two years of life. Mothers gain these nutrients through diet and additional supplementation when indicated. Infants gain a majority of these nutrients from their mothers after birth through breast milk (Brenna and Carlson). It has been shown that with additional supplementation of these nutrients, more progressive neurological development has occurred and accelerated progression in beginning milestones such as cognition and memorization activities have been demonstrated. It should also be noted that breast milk from omnivorous mothers had a higher concentration of DHA compared to vegetarian mothers' breast milk and formula feeding (Brenna and Carlson). These levels are measured in infants and adults through omega-3 panels which are blood tests that measure the acid content in red blood cells (Bernardi et al.).

In addition to being sourced from nutritional supplements, arachidonic acid, and DHA can be found in dairy fat. Dairy fat is a substance that not only provides essential fatty acids for cognitive function but also protein and minerals, such as calcium, phosphorous, and iron, necessary for human development (Erick; Brenna and Carlson). One critical component of breast milk and bovine milk is the milk fat globular membrane (Hernell et al.). This membrane is what surrounds the fat in mammalian milk. It has been shown that these membranes are associated with health benefits, including immune support and higher cognitive performance. Comparatively, infants fed formula without this membrane were shown to have lower cognitive function, increased rates of diabetes, and as a group, were found to have higher incidences of immunocompromise. For this reason, technology is continuing to work on adding bovine MFGM into formula to better support the infant population and the formula industry as a whole (Hernell et al.).

Neurological Development of the Neonate

During the gestational period, vitamin B12 deficiencies can be passed onto the fetus due to the decreased level of this nutrient in the mother. In one notable case, it was found that a vegan mother's infant had suffered an extensive decrease in neurological functioning between the ages of 3 months to 9 months. Specifically, these researchers noted a lack of fine motor skills and abnormal lethargic behavior (Wighton et al.). It was shown that the severity of the deficiency was caused by the deficiency in the mother's diet which had then passed onto the infant through the vitamin deficient breast milk. The infant slipped into a comatose state and was later diagnosed with megaloblastic anemia. The treatment in this circumstance was to provide extensive supplementation to the infant and mother with vitamin B12. This case demonstrated that the vitamin deficiency of the mother is what caused the deterioration of the infant at such an alarming rate. With the assistance of medical staff, additional parts of his brain became functional but he will likely suffer from lifelong neurological deficits. The current recommendation that all pregnant people adhering to plant-based diets supplement their food intake with vitamin B12 is to prevent these potential neurological deficits from occurring in the future (Wighton et al.).

Normal brain development requires specific micronutrients and macronutrients, such as folate and docosahexaenoic acid (Cheatham; Irvine et al.). In recent years, lack of folate has been shown to impact neurological development quite significantly. In a developing fetus's brain, folate is used to help form the neural tube, which is responsible for neurotransmission (Irvine et al.). At this time, research has only demonstrated improvement in neurological development with folate supplementation in animal studies. At this point, human studies conducted have been inconsistent due to the different methods used and the sample size of the population included (Irvine et al.).

Additionally, the absence of docosahexaenoic acid (DHA); also known as omega-3 fatty acids, has also been a nutrient linked to increased neurological development in fetuses and infants (Cheatham). DHA is passed from the mother to the fetus in the gestational period. Most of this transfer takes place during the last trimester of pregnancy. Normal levels of this nutrient help increase fetal cognitive skills in the early years of education and help reduce the risk of developing a neurological disorder (Cheatham).

Effects of Deficiency in Adults

It is important to look at the impacts and effects of nutritional deficiencies through all different stages of life; in adulthood the brain shifts and reacts constantly to changes in an individual's environment (Johnson et al., 2015). As reviewed thus far, some of the most notable deficiencies associated with a plant-based diet that demonstrate a negative correlation regarding neurological impact are vitamin B12 and omegas 3-6. In addition to the neurologic impacts on development; these deficiencies can contribute negatively to an adult's overall health status in a multitude of ways. Deficiency in vitamin B12 is linked to megaloblastic anemia as well as chronic inflammation of the digestive tract (Langan and Goodbred). This can lead to bowel disease and negatively impact the digestive system long term. Additionally, supplementation with omegas 3-6 has been found to improve symptoms of ADHD, specifically regarding behavior regulation and increased task completion as well as improvement in overall cognitive function, specifically relating to memory (Gow and Hibbeln; Bauer et al.).

Cognitive Effects of Deficiency in Adults

Cognition is the process of acquiring knowledge and understanding by using one's brain as well as senses (Bayne et al.). Cognitive function in adults can be measured in a multitude of ways. One of the best ways to measure cognition is through cognitive assessments (Snyder et al.).

The purpose of this study was to analyze the impacts of a plant-based and omnivorous diet on cognition. We reviewed a case that used a comprehensive neuropsychological battery with 132 test subjects (Gatto et al.). A neuropsychological battery is a type of assessment that helps assess neurological and cognitive functioning using an array of data analysis (*Neuropsychological Test Battery - an Overview | ScienceDirect Topics*). Before the initiation of the study, it was shown that 19.7% of the individuals had previous memory impairment. This was taken into consideration when analyzing the results. As this study was being completed, researchers analyzed various dietary groups. Some included vegans, vegetarians, pescetarians, and individuals who ate meat, dairy, and vegetables (Gatto et al.). The results show no substantial differences in cognitive ability between vegetarians and meat eaters. It was however noted that among all individuals adhering to diets that were stable and consistent, greater memory and language skills were present (Gatto et al.). In terms of differences in processing speed or reaction time among the various groups, the experiment was inconclusive, and no major differences were identified.

Neurological Effects of Deficiency in Adults

In terms of neurological development, by the time an individual reaches approximately 25 years of age, development is complete. A diet after this point will no longer threaten an individual's health or well-being from a developmental standpoint (Arain et al.). With this information, we can ascertain that in the early years, it is critical to supplement omega-3 fatty acids as well as vitamins B6 and B12 to promote optimal neurological function of the developing brain (Rathod et al.). These nutrients play a critical role in the neurological development of children and continue to increase healthy brain function in the adult years surrounding impulse control, cognitive function, and mental health. Deficiencies in these nutrients have been shown to cause adverse mental health effects and can lead to long-term problems if not addressed in the early years (Rathod et al.). The research currently available on this topic has so far been measured in small data samples, so consideration for all additional variables is essential. Although some cases showed no substantial negative effects, other individuals in various studies encountered unpleasant effects due to deficiencies in several of the nutrients examined in this study (Rathod et al.).

Psychiatric Effects of Deficiency in Adults

Vitamins B12 and B6 have been observed to have adverse effects that are most commonly associated with depression and anxiety (Berkins et al.). Studies have also shown that these deficiencies are more common in women and that supplementation did show positive development in brain matter over time (Berkins et al.).

Additionally, brain imaging showed that deficiencies in these vitamins can lead to loss of brain matter over time (Berkins et al.). Loss of this critical matter has been linked to schizophrenia and depression. Additionally, individuals who were observed to have heightened levels of B12, B6, and folate were shown to have larger amounts of gray matter and overall were at less risk for developing a mental illness later in life (Erickson et al.).

Future Direction

Since research investigating the connection between a plant-based diet and neurological development is a relatively new field of study, there are many ways that current research can continue moving forward. In a more recent study conducted, the physical structure of subcortical brain matter and function was observed and showed a positive relationship associated with vitamin B6 and 12 (Berkins et al.). However, more studies are needed to clarify the effects of plant-based diets on the brain and the overall health status of individuals. Additionally, studies utilizing cutting-edge techniques and longitudinal design are necessary to advance our understanding in this field. Past studies have demonstrated mixed results up to this point; for example, a study on B12 and folate deficiency highlighted no significant changes in terms of subcortical volumes or function. However, in a recent study, the opposite result was highlighted. In this study, the dangerous neurological effects that the lack of vitamin B12, and folate can have were showcased and supported by current research (Kapoor et al.). Because of the additional steps that vegetarians must take to ensure adequate nutritional value, they are more likely to have vitamin deficiencies that can negatively contribute to neurological developmental health at all ages to some degree.

Limitations and inconsistencies were seen throughout all areas of the research in this field. Two main areas of these inconsistencies were sample size and inconsistent results (Kapoor et al.) (Medawar et al.). It has been shown that a larger unbiased sample improves the generalizability of the results. In many studies, the standard deviation was much lower in many cases with larger sample sizes. Results with a lower standard deviation show greater precision of the results analyzed. In many of these studies, participants selected through online forum searches may lead to selection bias throughout these results. This bias compromises the validity of these results. More research in this field will lead to more accurate and consistent results for future studies regarding the neurological development and function of those adhering to plant-based diets.

Conclusion

As a whole, vegetarianism can provide many benefits to many individuals around the world. However, it is important to note that there are instances in which our bodies can be negatively affected by long-term restrictive diets (Benzie and Wachtel-Galor). Individuals who maintain vegetarian diets for a long duration may be deficient in essential nutrients that most meat eaters regularly ingest. Without consistent sources or supplements of nutrients found primarily in meat, vegetarians may subject themselves to poorer neurological development of the brain while increasing their propensity to develop future mental health issues (Wighton et al.; Berkins et al.). The development of the brain is something that will take place on a different timeline for everyone, but with adequate knowledge of the effects that vegetarianism can have, it sets more people up for greater success in the long term by providing the information to make dietary changes, including proper supplementation, part of their daily routine (Yaseen et al.).

The data we have analyzed has shown that an individual's diet does not just affect one part of the human body and also that these processes occur at various rates depending on factors including age and pre-existing health status. As stated previously, the food we eat produces the energy to fuel the development and growth of the whole body. In adults, we saw most commonly that there was a direct link between depression and anxiety related to the absence of B12 and B6 in a vegetarian diet (Berkins et al.). However, in the focus on neonatal cases, it was shown that the lack of arachidonic acid and docosahexaenoic acids were passed down in lower amounts to the developing fetus and could overall contribute to abnormal behavioral function in the first few months of life (Cheatham). These findings show that although research is limited at this time, continued study on this topic is essential to better understand how vitamin deficiency relates to neurological function and ultimately to improve outcomes.

Bibliography

1. “Amino Acid: Benefits & Food Sources.” *Cleveland Clinic*. Accessed 10 Oct. 2024.
2. Arain, Mariam, et al. “Maturation of the Adolescent Brain.” *Neuropsychiatric Disease and Treatment*, vol. 9, 2013, pp. 449–61. *PubMed Central*, https://doi.org/10.2147/NDT.S39776.
3. Bauer, Isabelle, et al. “Omega-3 Supplementation Improves Cognition and Modifies Brain Activation in Young Adults.” *Human Psychopharmacology: Clinical and Experimental*, vol. 29, no. 2, 2014, pp. 133–44. *Wiley Online Library*, https://doi.org/10.1002/hup.2379.
4. Bayne, Tim, et al. “What Is Cognition?” *Current Biology*, vol. 29, no. 13, July 2019, pp. R608–15. *www.cell.com*, https://doi.org/10.1016/j.cub.2019.05.044.
5. Beasley, Jeannette M., et al. “The Role of Dietary Protein Intake in the Prevention of Sarcopenia of Aging.” *Nutrition in Clinical Practice*, vol. 28, no. 6, Dec. 2013, pp. 684–90. *Europe PMC*, https://doi.org/10.1177/0884533613507607.
6. Benzie, Iris F. F., and Sissi Wachtel‐Galor. “Chapter 7 Biomarkers in Long‐Term Vegetarian Diets.” *Advances in Clinical Chemistry*, vol. 47, Elsevier, 2009, pp. 171–222. *ScienceDirect*, https://doi.org/10.1016/S0065-2423(09)47007-0.
7. Berkins, Samuel, et al. “Depression and Vegetarians: Association between Dietary Vitamin B6, B12 and Folate Intake and Global and Subcortical Brain Volumes.” *Nutrients*, vol. 13, no. 6, May 2021, p. 1790. *DOI.org (Crossref)*, https://doi.org/10.3390/nu13061790.
8. Bernardi, Juliana Rombaldi, et al. “Fetal and Neonatal Levels of Omega-3: Effects on Neurodevelopment, Nutrition, and Growth.” *The Scientific World Journal*, vol. 2012, Oct. 2012, p. 202473. *PubMed Central*, https://doi.org/10.1100/2012/202473.

9. Brenna, J. Thomas, and Susan E. Carlson. “Docosahexaenoic Acid and Human Brain Development: Evidence That a Dietary Supply Is Needed for Optimal Development.” *Journal of Human Evolution*, vol. 77, 2014, pp. 99–106.
10. Byrne, Mitchell K., et al. “Dietary Intakes of Long-Chain Polyunsaturated Fatty Acids and Impulsivity: Comparing Non-Restricted, Vegetarian, and Vegan Diets.” *Nutrients*, vol. 16, no. 6, Mar. 2024, p. 875. *DOI.org (Crossref)*, https://doi.org/10.3390/nu16060875.
11. Chaudron, Yohann, et al. “A Vegetable Fat-Based Diet Delays Psychomotor and Cognitive Development Compared with Maternal Dairy Fat Intake in Infant Gray Mouse Lemurs.” *Communications Biology*, vol. 7, no. 1, May 2024, pp. 1–14. *www.nature.com*, https://doi.org/10.1038/s42003-024-06255-w.
12. Cheatham, Carol L. “Nutritional Factors in Fetal and Infant Brain Development.” *Annals of Nutrition and Metabolism*, vol. 75, no. Suppl. 1, June 2020, pp. 20–32. *Silverchair*, https://doi.org/10.1159/000508052.
13. Chouraqui, Jean-Pierre. “Risk Assessment of Micronutrients Deficiency in Vegetarian or Vegan Children: Not So Obvious.” *Nutrients*, vol. 15, no. 9, 9, Jan. 2023, p. 2129. *www.mdpi.com*, https://doi.org/10.3390/nu15092129.
14. Clemente-Suárez, Vicente Javier, et al. “Neuro-Vulnerability in Energy Metabolism Regulation: A Comprehensive Narrative Review.” *Nutrients*, vol. 15, no. 14, July 2023. *www.ncbi.nlm.nih.gov*, https://doi.org/10.3390/nu15143106.
15. Cofnas, Nathan. “Is Vegetarianism Healthy for Children?” *Critical Reviews in Food Science and Nutrition*, vol. 59, no. 13, July 2019, pp. 2052–60. *tandfonline.com (Atypon)*, https://doi.org/10.1080/10408398.2018.1437024.
16. Crozier, Sarah R., et al. “Vegetarian Diet during Pregnancy Is Not Associated with Poorer

Cognitive Performance in Children at Age 6–7 Years." *Nutrients*, vol. 11, no. 12, 2019, p. 3029.

17. Czeizel, Andrew E., et al. "Folate Deficiency and Folic Acid Supplementation: The Prevention of Neural-Tube Defects and Congenital Heart Defects." *Nutrients*, vol. 5, no. 11, 11, Nov. 2013, pp. 4760–75. *www.mdpi.com*, https://doi.org/10.3390/nu5114760.
18. De Azevedo Paiva, Adriana, et al. "The Impact of Vitamin A Supplementation on the Immune System of Vitamin A-Deficient Children." *International Journal for Vitamin and Nutrition Research*, vol. 80, no. 3, June 2010, pp. 188–96. *DOI.org (Crossref)*, https://doi.org/10.1024/0300-9831/a000017.
19. Derbyshire, Emma. "Brain Health across the Lifespan: A Systematic Review on the Role of Omega-3 Fatty Acid Supplements." *Nutrients*, vol. 10, no. 8, 8, Aug. 2018, p. 1094. *www.mdpi.com*, https://doi.org/10.3390/nu10081094.
20. Erick, Miriam. "Breast Milk Is Conditionally Perfect." *Medical Hypotheses*, vol. 111, Feb. 2018, pp. 82–89. *ScienceDirect*, https://doi.org/10.1016/j.mehy.2017.12.020.
21. Erickson, Kirk I., et al. "Greater Intake of Vitamins B6 and B12 Spares Gray Matter in Healthy Elderly: A Voxel-Based Morphometry Study." *Brain Research*, vol. 1199, Mar. 2008, pp. 20–26. *PubMed Central*, https://doi.org/10.1016/j.brainres.2008.01.030.
22. Firth, Joseph, et al. "Food and Mood: How Do Diet and Nutrition Affect Mental Wellbeing?" *The BMJ*, vol. 369, June 2020, p. m2382. *PubMed Central*, https://doi.org/10.1136/bmj.m2382.
23. Gatto, Nicole M., et al. "Vegetarian Dietary Patterns and Cognitive Function among Older Adults: The Adventist Health Study-2." *Journal of Nutrition in Gerontology and Geriatrics*, vol. 40, no. 4, Oct. 2021, pp. 197–214. *Taylor and Francis+NEJM*,

https://doi.org/10.1080/21551197.2021.1965939.

24. Gibbs, Joshua, and Francesco P. Cappuccio. “Common Nutritional Shortcomings in Vegetarians and Vegans.” *Dietetics*, vol. 3, no. 2, 2, June 2024, pp. 114–28. *www.mdpi.com*, https://doi.org/10.3390/dietetics3020010.
25. Gow, Rachel V., and Joseph R. Hibbeln. “Omega-3 and Treatment Implications in Attention Deficit Hyperactivity Disorder (ADHD) and Associated Behavioral Symptoms.” *Lipid Technology*, vol. 26, no. 1, Jan. 2014, pp. 7–10. *DOI.org (Crossref)*, https://doi.org/10.1002/lite.201400002.
26. Griebel, Craig P., et al. “Management of Spontaneous Abortion.” *American Family Physician*, vol. 72, no. 7, Oct. 2005, pp. 1243–50.
27. Hall, Kevin D., et al. “Energy Balance and Its Components: Implications for Body Weight Regulation123.” *The American Journal of Clinical Nutrition*, vol. 95, no. 4, Apr. 2012, pp. 989–94. *ajcn.nutrition.org*, https://doi.org/10.3945/ajcn.112.036350.
28. Harden, Alastair. “The Ancient Idea of Vegetarianism.” *Animals in the Classical World: Ethical Perspectives from Greek and Roman Texts*, edited by Alastair Harden, Palgrave Macmillan UK, 2013, pp. 64–86. *Springer Link*, https://doi.org/10.1057/9781137319319_4.
29. Heaney, Robert P. “Long-Latency Deficiency Disease: Insights from Calcium and Vitamin D123.” *The American Journal of Clinical Nutrition*, vol. 78, no. 5, Nov. 2003, pp. 912–19. *ScienceDirect*, https://doi.org/10.1093/ajcn/78.5.912.
30. Hernell, Olle, et al. “Clinical Benefits of Milk Fat Globule Membranes for Infants and Children.” *The Journal of Pediatrics*, vol. 173, June 2016, pp. S60–65. *www.jpeds.com*, https://doi.org/10.1016/j.jpeds.2016.02.077.

31. Innis, Sheila M. “Dietary Omega 3 Fatty Acids and the Developing Brain.” *Brain Research*, vol. 1237, Oct. 2008, pp. 35–43. *ScienceDirect*, https://doi.org/10.1016/j.brainres.2008.08.078.
32. Irvine, Nathalie, et al. “Prenatal Folate and Choline Levels and Brain and Cognitive Development in Children: A Critical Narrative Review.” *Nutrients*, vol. 14, no. 2, Jan. 2022, p. 364. *PubMed Central*, https://doi.org/10.3390/nu14020364.
33. Jen, Melinda, and Albert C. Yan. “Syndromes Associated with Nutritional Deficiency and Excess.” *Clinics in Dermatology*, vol. 28, no. 6, Nov. 2010, pp. 669–85. *ScienceDirect*, https://doi.org/10.1016/j.clindermatol.2010.03.029.
34. Kahleova, Hana, et al. “Cardio-Metabolic Benefits of Plant-Based Diets.” *Nutrients*, vol. 9, no. 8, 8, Aug. 2017, p. 848. *www.mdpi.com*, https://doi.org/10.3390/nu9080848.
35. Kapoor, Aneel, et al. “Neuropsychiatric and Neurological Problems among Vitamin B12 Deficient Young Vegetarians.” *Neurosciences Journal*, vol. 22, no. 3, July 2017, pp. 228–32. *nsj.org.sa*, https://doi.org/10.17712/nsj.2017.3.20160445.
36. Kennedy, David O., and Crystal F. Haskell. “Vitamins and Cognition.” *Drugs*, vol. 71, no. 15, Oct. 2011, pp. 1957–71. *Springer Link*, https://doi.org/10.2165/11594130-000000000-00000.
37. Langan, Robert C., and Andrew J. Goodbred. “Vitamin B12 Deficiency: Recognition and Management.” *American Family Physician*, vol. 96, no. 6, 2017, pp. 384–89.
38. MacArthur, Michael R., et al. “Total Protein, Not Amino Acid Composition, Differs in Plant-Based versus Omnivorous Dietary Patterns and Determines Metabolic Health Effects in Mice.” *Cell Metabolism*, vol. 33, no. 9, Sept. 2021, pp. 1808-1819.e2. *PubMed Central*, https://doi.org/10.1016/j.cmet.2021.06.011.

39. Mb, Ruby. “Vegetarianism. A Blossoming Field of Study.” *Appetite*, vol. 58, no. 1, Feb. 2012. *pubmed.ncbi.nlm.nih.gov*, https://doi.org/10.1016/j.appet.2011.09.019.
40. Medawar, Evelyn, et al. “The Effects of Plant-Based Diets on the Body and the Brain: A Systematic Review.” *Translational Psychiatry*, vol. 9, Sept. 2019, p. 226. *PubMed Central*, https://doi.org/10.1038/s41398-019-0552-0.
41. Neufingerl, Nicole, and Ans Eilander. “Nutrient Intake and Status in Adults Consuming Plant-Based Diets Compared to Meat-Eaters: A Systematic Review.” *Nutrients*, vol. 14, no. 1, Dec. 2021, p. 29. *PubMed Central*, https://doi.org/10.3390/nu14010029.
42. *Neuropsychological Test Battery - an Overview | ScienceDirect Topics*. Accessed 11 Oct. 2024.
43. Niemoller, Tiffany D., and Nicolas G. Bazan. “Docosahexaenoic Acid Neurolipidomics.” *Prostaglandins & Other Lipid Mediators*, vol. 91, no. 3, Apr. 2010, pp. 85–89. *ScienceDirect*, https://doi.org/10.1016/j.prostaglandins.2009.09.005.
44. Papier, Keren, et al. “Comparison of Major Protein-Source Foods and Other Food Groups in Meat-Eaters and Non-Meat-Eaters in the EPIC-Oxford Cohort.” *Nutrients*, vol. 11, no. 4, Apr. 2019, p. 824. *PubMed Central*, https://doi.org/10.3390/nu11040824.
45. Pawlak, Roman, et al. “Iron Status of Vegetarian Adults: A Review of Literature.” *American Journal of Lifestyle Medicine*, vol. 12, no. 6, Dec. 2016, pp. 486–98. *PubMed Central*, https://doi.org/10.1177/1559827616682933.
46. Petti, Alessandra, et al. “Vegetarianism and Veganism: Not Only Benefits but Also Gaps. A Review.” *Progress in Nutrition*, vol. 19, Oct. 2017, pp. 229–42. *ResearchGate*, https://doi.org/10.23751/pn.v19i3.5229.
47. Rathod, Richa, et al. “Novel Insights into the Effect of Vitamin B12 and Omega-3 Fatty

Acids on Brain Function." *Journal of Biomedical Science*, vol. 23, Jan. 2016, p. 17. *PubMed Central*, https://doi.org/10.1186/s12929-016-0241-8.

48. Sanders, T. A. B. "Vegetarian Diets and Children." *Pediatric Clinics of North America*, vol. 42, no. 4, Aug. 1995, pp. 955–65. *ScienceDirect*, https://doi.org/10.1016/S0031-3955(16)40024-6.
49. Sato, Hideaki, et al. "Protein Deficiency-Induced Behavioral Abnormalities and Neurotransmitter Loss in Aged Mice Are Ameliorated by Essential Amino Acids." *Frontiers in Nutrition*, vol. 7, Mar. 2020, p. 23. *PubMed Central*, https://doi.org/10.3389/fnut.2020.00023.
50. Services, Department of Health &. Human. *Protein*. Department of Health & Human Services, http://www.betterhealth.vic.gov.au/health/healthyliving/protein. Accessed 11 Oct. 2024.
51. Snyder, Peter J., et al. "Assessment of Cognition in Mild Cognitive Impairment: A Comparative Study." *Alzheimer's & Dementia*, vol. 7, no. 3, May 2011, pp. 338–55. *ScienceDirect*, https://doi.org/10.1016/j.jalz.2011.03.009.
52. Stiles, Joan, and Terry L. Jernigan. "The Basics of Brain Development." *Neuropsychology Review*, vol. 20, no. 4, 2010, pp. 327–48. *PubMed Central*, https://doi.org/10.1007/s11065-010-9148-4.
53. Sun, Peter D., et al. "Overview of Protein Structural and Functional Folds." *Current Protocols in Protein Science*, vol. 35, no. 1, Feb. 2004. *DOI.org (Crossref)*, https://doi.org/10.1002/0471140864.ps1701s35.
54. Tardy, Anne-Laure, et al. "Vitamins and Minerals for Energy, Fatigue and Cognition: A Narrative Review of the Biochemical and Clinical Evidence." *Nutrients*, vol. 12, no. 1, Jan.

2020, p. 228. *PubMed Central*, https://doi.org/10.3390/nu12010228.

55. Tuso, Philip J., et al. “Nutritional Update for Physicians: Plant-Based Diets.” *The Permanente Journal*, vol. 17, no. 2, 2013, pp. 61–66. *PubMed Central*, https://doi.org/10.7812/TPP/12-085.
56. Wang, Thomas J., et al. “Vitamin D Deficiency and Risk of Cardiovascular Disease.” *Circulation*, vol. 117, no. 4, Jan. 2008, pp. 503–11. *ahajournals.org (Atypon)*, https://doi.org/10.1161/CIRCULATIONAHA.107.706127.
57. Wighton, M. C., et al. “Brain Damage in Infancy and Dietary Vitamin B12 Deficiency.” *Medical Journal of Australia*, vol. 2, no. 1, 1979, pp. 1–3. *Wiley Online Library*, https://doi.org/10.5694/j.1326-5377.1979.tb112643.x.
58. Yaseen, Nabeel R., et al. “Genetics of Vegetarianism: A Genome-Wide Association Study.” *PLOS ONE*, vol. 18, no. 10, Oct. 2023, p. e0291305. *PLoS Journals*, https://doi.org/10.1371/journal.pone.0291305.
59. Zhang, Ruohan, et al. “Associations of Dietary Patterns with Brain Health from Behavioral, Neuroimaging, Biochemical and Genetic Analyses.” *Nature Mental Health*, vol. 2, no. 5, May 2024, pp. 535–52. *www.nature.com*, https://doi.org/10.1038/s44220-024-00226-0.